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"An Arctic Modeling Center on Ocean-Ice-Atmosphere Interactions"


(NASA-CR-198803) AN ARCTIC
MODELING CENTER ON
OCEAN-ICE-ATMOSPHERE INTERACTIONS
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Background and Objectives:

The strong sensitivity of polar climate to the simulated surface fluxes of heat, moisture and momentum is undoubtedly responsible for many of the deficiencies in the simulations of the Arctic by global climate models. However, rigorous explanations of these deficiencies have been lacking because of the complexity of the interactions between the atmosphere (including clouds), ocean, land, snow and sea ice. The approach we have taken to reach an understanding of the role of the Arctic in climate is a high resolution limited area model system approach. This approach, while expensive and difficult, is physically based and has yielded promising preliminary results, and hence offers a wide range of applications. The Arctic Region Climate System Model (ARCSyM) has been under development since 1992, and is now recognized as a leading regional model of the Arctic. The ARCSyM is currently being used by investigators at NCAR, University of Colorado, Rutgers University, Los Alamos National Laboratory, Pennsylvania State University and Byrd Polar Research Center.

ARCSyM has been developed to simulate coupled interactions among the atmosphere, sea ice, ocean and land surface of the western Arctic. The atmospheric formulation is based upon the NCAR regional climate model RegCM2, and includes the CCM2 radiation scheme and the Biosphere-Atmosphere Transfer Scheme (BATS). The dynamic-thermodynamic sea ice model includes the Hibler-Flato cavitating fluid formulation and the Parkinson-Washington thermodynamic scheme linked to a swamp ocean.

The ultimate goals of the research were

- to provide a prioritization of the problems and issues confronting modelers of the Arctic system;
- to create a climate system model appropriate for long term simulations of high latitude climate;
- to create a coupled model for the study of individual phenomena such as polynya formation and land surface run-off which require such an approach.

Achievements:

Simulations have been performed at a range of horizontal resolutions, from 7km to 63km, in order to assess the performance of the model and guide the development of new, high latitude specific physical parameterizations. Experiments at the coarser resolutions have addressed the model sensitivity to sea ice dynamics (rarely done in global climate models), the sub-grid-scale moisture treatment, to ice phase physics in the explicit moisture parameterization, to changes in the relative humidity threshold for the autoconversion of cloud water to rainwater, and to changes in cloud parameters affecting cloud-radiative interactions. In particular, it has been found that the parameterization of ice dynamics and the ice phase in atmospheric moist processes are crucial in working towards an accurate Arctic simulation. Further work in these areas is already underway under a separate NSF grant. In addition, it is clear that even with simple representations of these processes included, there are deficiencies in the resulting model simulations, which point to the need for similar systematic examination of other parameterizations, including radiative processes, soil hydrology and ocean circulation. Since the implicit physical schemes outperform the more physically representative explicit schemes in the Arctic, more work needs to be done on these physically-based schemes before their inclusion into GCMs is warranted. This will continue with NSF funding.

Simulations at finer resolutions have addressed the performance of the model in simulating specific events, such as the formation of the St Lawrence Island polynya (SLIP). Satellite

observations of the polynya have previously been limited to large-scale, low resolution imagery or costly field expeditions that are highly dependent on season and cloud conditions. The recently launched European Space Agency Earth Remote Sensing Satellite 1 (ERS-1) which carries a Synthetic Aperture Radar (SAR) has made a new form of high spatial and temporal resolution imagery available for use. As the SAR is an active C-band microwave instrument, it is virtually unaffected by darkness, or by the dense cloud cover which tends to be prevalent during Bering Sea winters. The resulting SAR imagery can also be processed to create ice motion products. Further, SAR imagery can be combined with the more traditional remote sensing products (i.e. AVHRR and SMM/I) to produce a comprehensive picture of the ice circulation and the process of polynya formation. Modeling a SLIP event (the opening and closing of the polynya) has been a difficult task due to the relatively small size of the polynya leading to the requirement for a regional scale coupled atmosphere/sea ice model. With the development of ARCSyM, simulation of the SLIP is now possible. The use of the newly-acquired remote sensing products can now be extended further to model validation in addition to observation of the polynya event.

High latitude air-sea-ice interaction is the main conduit through which the deep ocean communicates with the rest of the climate system. A key element in modeling and predicting the oceanic impact on climate is understanding the processes which control the near surface exchange of heat, salinity and momentum. Thus, the last phase of the NASA-funded project involved the coupling of a regional ocean circulation model to complete the basic suite of component models in the climate system model, in order to address this question. This work was undertaken in conjunction with researchers at Rutgers University. It has been found in simulations with the fully coupled climate system model that the ocean circulation has profound effects on the local atmospheric circulation through its control of ice distribution, and hence surface fluxes. It is now planned to couple the ARCSyM to the CCM2 global climate model, in collaboration with researchers at the Byrd Polar Research Center. By using this two-way coupling method, how the global climate is influenced by the polar regions and how the polar climate is affected by other regions of the globe will be quantified.

Participants:

Dr. Amanda Lynch, Assistant Professor of Geophysics
Mr. David Bailey, Research Programmer
Mr. William Chapman (U. Illinois)
Dr. David Musgrave, Assist. Prof. of Marine Science
Dr. Andrey Proshutinsky, Research Associate
Dr. Jeffrey Tilley, Assist. Research Professor of Geophysics
Dr. John Walsh, Wadati Visiting Professor, Co-Princ. Invest.
Dr. Gunter Weller, Professor of Geophysics, Princ. Investigator

On subcontracts:

Dr. Dale Haidvogel (Rutgers University)
Ms. Katherine Hedstrom (Rutgers University)

Students:

Stefan Beine (summer intern)
Amirtha Srinivasan, PhD student
Ryan Woodard, PhD student

Papers and Presentations:

Reports:

Weller, G., J. Walsh, A. Lynch, W. Chapman, and D. Musgrave, 1993: An Arctic modeling center on ocean-ice-atmosphere interactions, NASA Triennial Report.

Selected Conference Proceedings:

Lynch, A.H., Weller, G., Walsh, J.E., Chapman, W., 1995: A Regional Model for Studies of the Arctic Atmosphere-Ocean-Land System, Proc. AGU 1993 Fall Meeting, San Francisco, USA, Dec. 1993, invited.

Lynch, A.H., Chapman, W., Walsh, J.E., Weller, G., 1995: Development of a Regional Climate Model of the Western Arctic. Proc. AMS 4th Conference on Polar Meteorology and Oceanography, Dallas, USA, Jan. 1995.

Lynch, A.H., Glueck, M.F., Chapman, W., Bailey, D.A., Walsh, J.E., 1995: The Use of Synthetic Aperture Radar Data for Verification of a Coupled Atmosphere-Sea Ice Regional Model. Proc. AMS 4th Conference on Polar Meteorology and Oceanography, Dallas, USA, Jan. 1995.

Refereed Papers:

Walsh, J.E., Lynch, A.H., Chapman, W. & Musgrave, D, 1993.: A Regional Model for Studies of Atmosphere-Ice-Ocean Interaction in the Western Arctic, Met.Atmos.Physics, 51, 179-194.

Lynch, A.H., Chapman, W. Walsh, J.E. & Weller, G., 1995: Development of a Regional Climate Model of the Western Arctic. J.Climate, 8, 1555-1570.

Lynch, A.H., Glueck, M.F., Chapman, W., Bailey, D.A. & Walsh, J.E., 1995: The Use of Remote Sensing Data for Verification of a High Resolution Coupled Atmosphere-Sea Ice Regional Model. Monthly Weather Review, (in review).

Lynch, A.H., Bailey, D.A., Hedstrom, K. & Tilley, J.S., 1995: The Impact of the Ocean Circulation on the Annual Cycle of a Region Climate Model. J.Climate, (in preparation).

Other future presentations:

Lynch, A.H., Bailey, D.A. & Tilley, J.S., 1995: The Impact of the Ocean Circulation on the Annual Cycle of a Region Climate Model. IUGG, Boulder, CO, July 1995.

Lynch, A.H., Bailey, D.A., 1995: Regional Climate Modelling at the Arctic Region Supercomputing Center, Cray User's Group Symposium, Fairbanks, AK, September 1995, invited.